# DREDGING

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TABLE OF CONTENTS

List of Figures

# INTRODUCTION

## DEFINITION

Dredging is defined as the removal of soil or material from the bottom of a river, lake, or ocean harbor. Dredges are the machines used for this purpose and consist of powerful hoisting or suction equipment mounted on barge-like floats. These machines are used to deepen or widen waterways, to reclaim land, to build dikes or foundations, and to mine alluvial deposits of precious metals.

The various types of dredges can be broken into two major groups, the Mechanical and the Hydraulic dredges. Mechanical dredges use physical contact to lift the dredged material, then load the dredged materials onto barges moored alongside. The barges then take the materials for ultimate disposal. Hydraulic dredges use suction pumps to lift the sediment into the dredge through pipes. The sediment is then handled in several different ways, depending on the type of equipment being used. Sidecasting and Dustpan dredges will pump the material over the side immediately. Hopper dredges will store the materials until full, then take the materials to a location to be disposed of either at sea or inland. Cutterhead dredges will use a series of pumps to carry the material to disposal without the dredge ever leaving its area of operation.

## HISTORY

Early civilization made its start in close proximity to bodies of water. Early in man's history, we needed water to meet the most basic needs of survival. As humans progressed, the waters provided means for greater needs to be satisfied, such as taming the rivers for irrigation, keeping silt out of harbors for navigation and keeping the seas from intruding inland. Today, almost half of the world's population lives less than 300 miles from open water.

The use of slaves and the peoples of conquered nations made the earliest of the hydraulic projects possible. This was a means of very low cost labor. The technology consisted of shovels and picks and the projects were made on dry land. The work was back breaking and tiresome, but it is from these early projects that the technology improved to the super efficient machines of today. Ancient cultures in the Middle East, North Africa and China all constructed dikes, canals, embankments and irrigation works to provide for their settlements. In the 7th century BC, the Assyrian king Sennacherib constructed a 480-mile long, 65-foot wide stone-lined canal to bring fresh water to his capital Nineveh. Compared to 20th century standards, it is surprising to learn that the project, which included a 1080-foot long aqueduct, was completed in only one year and three months time.

Using the primitive tools and the non-skilled labor, the early peoples were still able to erect some amazing works. The Roman architect Vitruvius describes how stone harbor moles should be constructed, filling in the space between two double dam walls with clay, packed in reed baskets, or using wicker work and clay in reed mats. After that, the drained bottom within both dams could be leveled and finally the stones would be deposited on the dry and leveled bottom. Roman engineering, slave laborers and teams of soldiers were able to create a marine infrastructure, parts of which still exist today.

After the Roman Empire collapsed, Europe went into the dark ages. There were few projects of any magnitude since there were no central governments to execute them. However, larger projects started to be conceived again in the Low Countries of Europe between 1075 and 1175 when the lands from Holland to Normandy were systematically diked. This project and later attempts to

keep the sea out would prove to be futile attempts to reclaim land until the introduction of the windmill in the 1500's. In the war to regain land from the sea, people had to come up with a way to carry out dredging projects in the wet. A very primitive instrument was the hand drag. It consisted of a metal ring with a bucket attached at the end of a 10-foot pole. Although very basic in design, this device is still used today for small jobs.

As trade with overseas parties became more popular, the harbors had to be kept deep enough to handle the larger ships that were being built. The battle is against the silt that builds up at the mouths of rivers. Brugge, an early European trading center, was connected to the sea by a canal that was dug in the 11$^{th}$ century. It was a center of trade for merchants from Scandinavia to Southern Europe. The sediment build up in the canal, despite the early attempts at maintenance dredging, was serious enough that by the 14$^{th}$ century ships had to be offloaded at coastal towns and shipped overland to Brugge.

**THE NEW MACHINES**

From the Middle Ages to the Industrial Revolution there would be revolutionary ideas in dredging equipment, but they had to wait for the steam engine before there could be any relief to the need for human sweat or animal labor. Devices for loosening the soil came in the form of iron scrapers fastened to the hulls of ships. As the ship sailed, the scraper would be dragged over the bottom of the harbor. This only loosened the soil, and it was thought currents would be able to carry away

the sediment. Inventors like Leonardo Di Vinci would come up with either hand or horse drawn

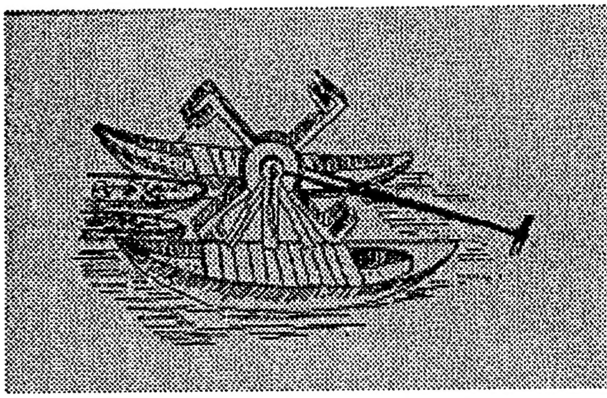

Figure 1. Leonardo Di Vinci's design

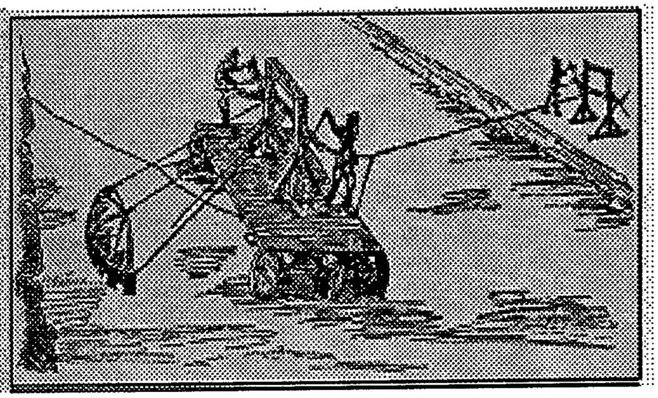

Figure 2. Mud Rake

rakes that were dragged over the bottom. In the early 19th century, the rakes and harrows were then mounted on rafts and pulled by men or horses from the shore (see figure 1 & 2).

These devices loosened the soil, the removal still had to be accomplished. In the 17th century, there were ideas about using an endless chain to be used with a hand drag to perform soil removal. This idea led to the creation of the Mud Mill. This device used an endless chain that was driven by a wheel. Manpower, and later horsepower, drove the wheel. The endless chain had little planks, and later buckets, to carry the soil away. Once again, the labor was cheap. A criminal who was found guilty in court could be sentenced to hard labor on the wheel. In the 18th century, the French developed the spoon dredger, which was the precursor of the modern dipper and bucket dredges.

**STEAM**

In the 19th century a 12 horsepower steam engine was added to power a bucket ladder. The first production realized 90 tons of sand and 60 to 70 tons of gravel per hour. No longer was there a need for a large labor pool to work the wheel. To replace dynamite as a means of loosening rock for removal, new dredges would drop a heavy chisel to loosen the rock. Then a bucket chain would

remove the pieces. A friction clutch was added in 1808 to prevent the whole machine from breaking up when the system hit harder materials.

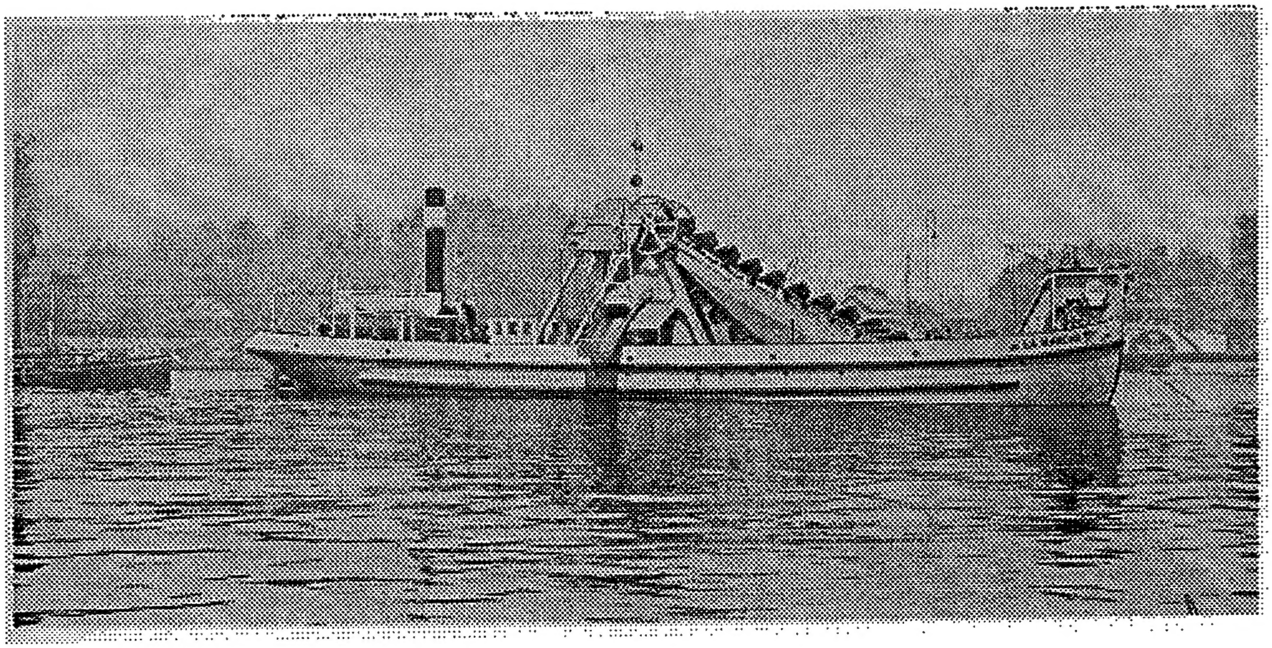

Figure 3. Early Ladder Dredge.

The next improvement to the steam dredgers came decades later. The bucket ladders had been installed on the sides of the vessel, the newer designs would have the ladders installed amidships (see figure 3). Later in the 19th century, the barges the dredging equipment were installed on would become self-propelled by way of a paddlewheel. Being self-propelled would make it easier to maneuver the dredge into position. Finally, the introduction of the centrifugal pump coupled with the steam engine created a powerful suction pump. The French engineers who created the pump claimed the new device was eight to ten times as efficient as the existing bucket dredgers.

The three inventions of the 19th century that lead to the dredges of today were the steam engine, the centrifugal pump and the rotating cutterhead. The Second World War saw the steam engine get replaced by the diesel engine. The new diesel engines improved efficiency due to the ease of

refueling and by removing stokers as a requirement to keep the furnaces hot. This aided the suction dredgers foremost. The plain suction, the cutterhead and the hopper dredges had reached perfection. The plain suction dredges reached their peak in the 1950's and 1960's when there was a great demand for sand in road and land reclamation projects. Their numbers have been reduced drastically since then. The cutterhead and the hopper dredges have each enjoyed growth from the 1970's to today.

## THE MODERN MACHINES AND TECHNIQUES

### GETTING STARTED

The Army Corps of Engineers first started dredging operations in 1824 after receiving authorization from the U.S. Congress to remove sandbars and snags from the navigable rivers. Today, the Corps is responsible for the planning, design, construction, operation and maintenance of the nations navigable waterways. Through their history, the Corps has developed a set of considerations to be met before a dredging project can commence.

a. Selection of proper dredge plant for a given project

b. Determining whether or not there will be dredging of contaminated material.

c. Adequate disposal facilities.

d. Long-term planning for maintenance dredging projects.

e. Characterization of sediments to be dredged to support an engineering design of confined disposal areas

f. Determining the levels of suspended solids from disposal areas and dredge operations.

g. Disposal of contaminated sediments.

h. Disposal in remote areas.

i. Control of dredging operation to ensure environmental protection.

j. Containment area management for maximizing storage capacity.

Through these guidelines, the type of equipment and the disposal practices will be determined (see Appendix I for Corps and Industry Dredge Totals).

## ALTERNATIVES TO DREDGING

In the investigation phase of a dredging project, it should be determined if dredging is required or if the requirements of the user can be completed by an alternative method. Some practical solutions to dredging include:

1. Holding up the sedimentation by a silt screen in the harbor mouth.
2. Catching the instreaming bottom sediment in a pit in the harbor mouth, sometimes in combination with a stationary suction system.
3. Removing local shallow spots by a bed leveler
4. Increasing consolidation of the bottom materials

Additionally, good land use practices upstream will reduce the amount of sediment reaching the streams, and therefore reduce the build up of sediments at river mouths.

## DREDGE EQUIPMENT

The type of equipment to be used on a job depends on the materials to be removed as determined by the initial investigations. Hydraulic (Suction) Dredging is used on loose materials and is primarily for maintenance operations. Mechanical Dredging is used to remove either loose or more compacted materials and is more commonly used on new work projects. Depending on the scope

of work, it may be more efficient to use a combination of hydraulic and mechanical dredges. The primary factors in determining the type of equipment to be used include:

1. Physical characteristics of material to be dredged.
2. Quantities of material to be dredged.
3. Dredging depth.
4. Distance to disposal area.
5. Physical environment of and between the dredging and disposal areas.
6. Contamination level of sediments.
7. Method of disposal.
8. Production required.
9. Type of dredges available.

This gives a guideline for the selection of the type of dredge to use. The description of the dredge types follows.

**Hopper Dredge**

Hopper dredges are self-propelled seagoing vessels that have the lines of ocean going vessels. They are equipped with propulsion equipment, sediment containers, dredge pumps, and other special equipment required to perform the sediment removal operations. The hopper dredges propulsion equipment must be powerful enough to maneuver the dredge during operations in areas that have a strong currents or rough open seas. The material is removed by dredge pumps through dragarms connected to drags in contact with the channel bottom. The removed material is discharged into hoppers built into the vessel (see Figure 4). Hopper capacities for large vessels range from 2,000 to 6,000 cubic yards and smaller vessels have capacities from 500 to 2,000 cubic

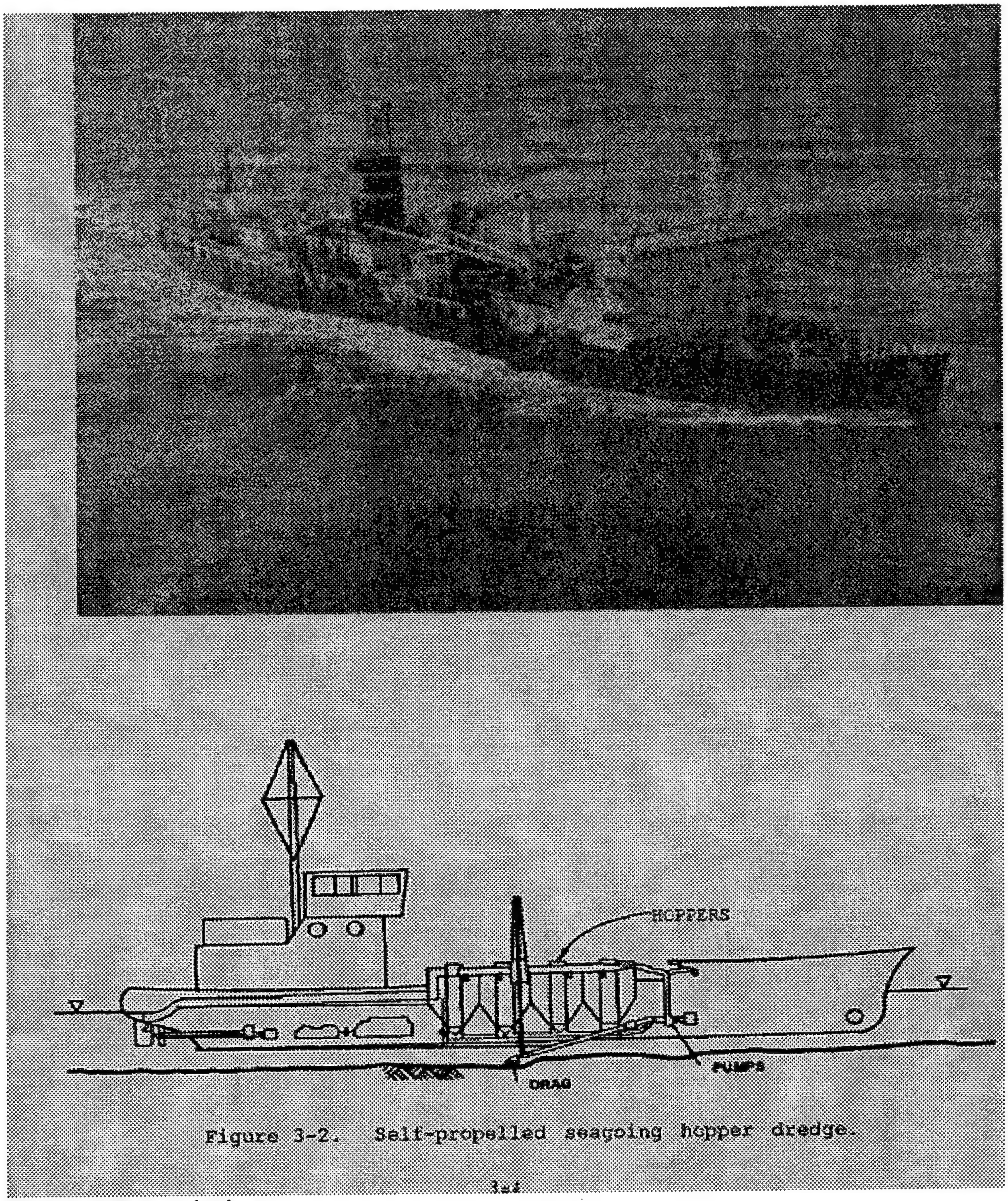

Figure 4. Hopper dredge.

yards. The depths that can be obtained are from 10 to 80 feet. While operating, the dredge will be traveling at a speed of 2 to 3 miles per hour. The operation is completed using progressive

traverses over the contracted area. Once the hoppers are fully loaded, the dredge must move to a disposal site to unload before resuming operations. The unloading is accomplished through opening doors at the bottom of the hoppers and allowing the dredged materials to sink in open-water disposal sites or by pumping the dredged materials to upland disposal sites. The Army Corps of Engineers have a hopper dredge, called the Currituck, that accomplishes the disposal operation by the having the length of the hull split open up to eleven feet allowing the dredged materials in the hull to sink.

The hopper dredge is advantageous in areas where there is rough, open waters and where boat traffic will be operating in close proximity. Because the hopper dredge is self-propelled, it can maneuver without obstructing traffic. This dredge type can be relocated to new job sites quickly. The dredge type will be the most economical to use in locations where the disposal areas are not within the distance that a hydraulic pipeline could reach.

The hopper dredge is limited by its deep draft. Shallow areas are not accessible by the hopper dredge. The hopper dredge cannot dredge continuously because it has to unload its hoppers when they fill, and it is not effective for removing hardpacked sand or consolidated clays. If the soil to be removed contains contaminated sediment, the hopper dredge efficiency is reduced because it will have to dispose the material in an upland site instead of ocean disposal.

**<u>Cutterhead Dredge</u>**

This is the most common type of dredge available today. This is a hydraulic type of dredge that has a rotating cutter at the end of the dredge pipe. This allows the dredge to remove the

hardpacked sands and the consolidated clays that the hopper dredges are limited by. This dredge is also equipped with the ability to pump dredged materials long distances to upland disposal sites. The cutterhead dredge operates by using two stern spuds and port and starboard swing cables to make the cutterhead swing side to side over the area to be dredged (see figure 5). The starboard

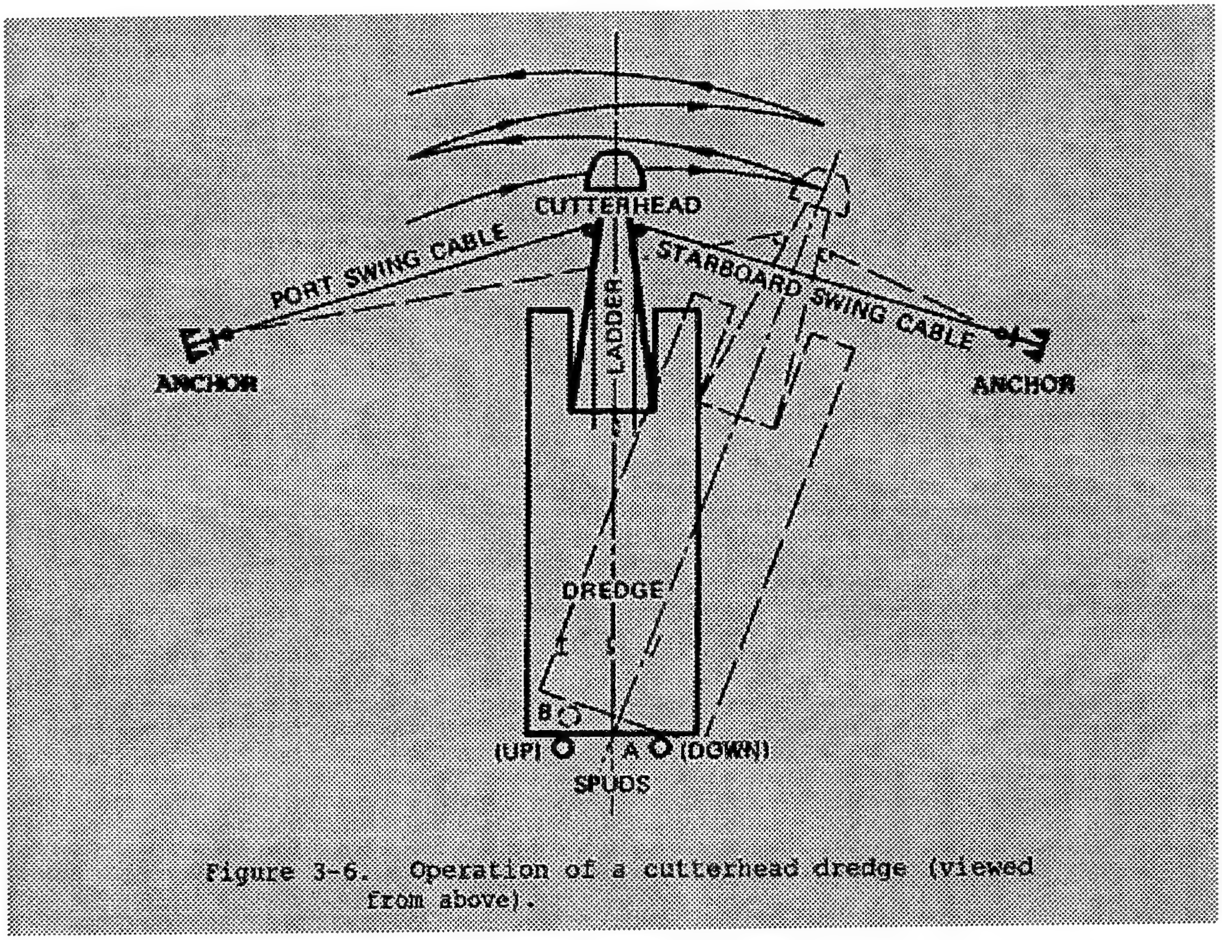


Figure 5. Cutterhead diagram of operations

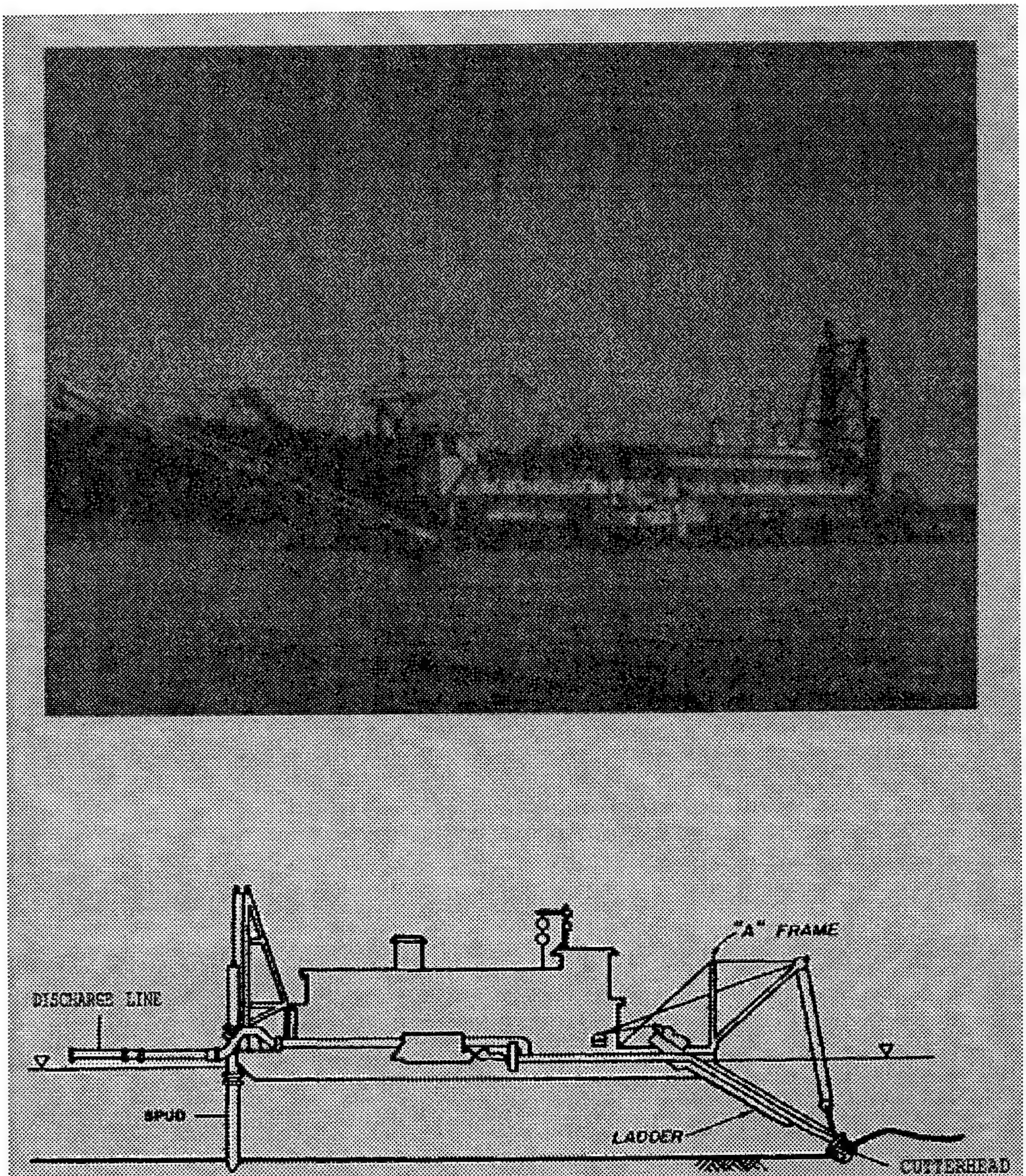


Figure 3-3. Hydraulic pipeline cutterhead dredge.

Figure 6. Cutterhead Dredge Diagram

spud will be engaged (down) and the starboard swing cable will be pulled to draw the cutterhead to the right until it reaches the edge of the contracted dredge area. Then, the starboard spud is raised and the port spud is engaged. The port side swing cable is pulled, drawing the cutterhead back to the left. The cutterhead dredge can dispose of the dredged material in the open-water by using a floating discharge pipeline (see figure 6). The usual distance that the dredge can discharge to is about 3 miles. When discharging to commercial land reclamation areas or landfill purposes, booster pumps can be used to increase the distance to 15 miles. The cutterhead enables the dredge to remove the hardpacked materials, but if the material does not require the use of the cutter the head can be removed, making the equipment into a plain suction dredger. The cutterhead dredge is ideal for maintaining harbors, canals and outlet channels where the wave height does not exceed 2 to 3 feet in height.

This dredge type is the most common in use in the United States because it has the ability to cut through most types of sediment and it can pump the materials up to 15 miles to upland disposal sites. Because of the ability to pump the dredged materials to disposal sites, the cutterhead dredge can maintain virtually round the clock dredging operation, making it the most efficient dredge platform.

The cutterhead is limited by the inability to dredge in rough seas. It is a rigid connection (ladder) that attaches the cutterhead to the vessel. In rough seas, the connection can be severely damaged because of the rigidity of the connection. This dredge type is not self-propelled, and cannot maneuver if it is operating in a navigation channel. That may cause some disruption of the boat traffic and must be considered in the planning stages. The spuds and swing cable are used to keep

the dredge on site, and in areas of loose sand and flowing currents scouring is a problem for keeping the dredge platform on location (see Appendix II for operational characteristics of Hopper and Cutterhead Dredge types).

**<u>Dustpan Dredge</u>**

This hydraulic dredge uses a widely flared dredging head that has pressure water jets installed. The water jets loosen the sediments, which are then captured in the dustpan head as it winches forward. This dredge type was made to deal with riverbeds that primarily contain loose sand and gravel. The pump on this dredge type is not as powerful as on the other dredge types and the dredged materials are discharged only 800 to 1000 feet from the platform into open water outside of the navigation channel. The dustpan dredge uses two anchors and cables to pull the dredge upstream (see Figure 7). After dropping the anchors, the dredge drifts downstream about 500 feet to begin

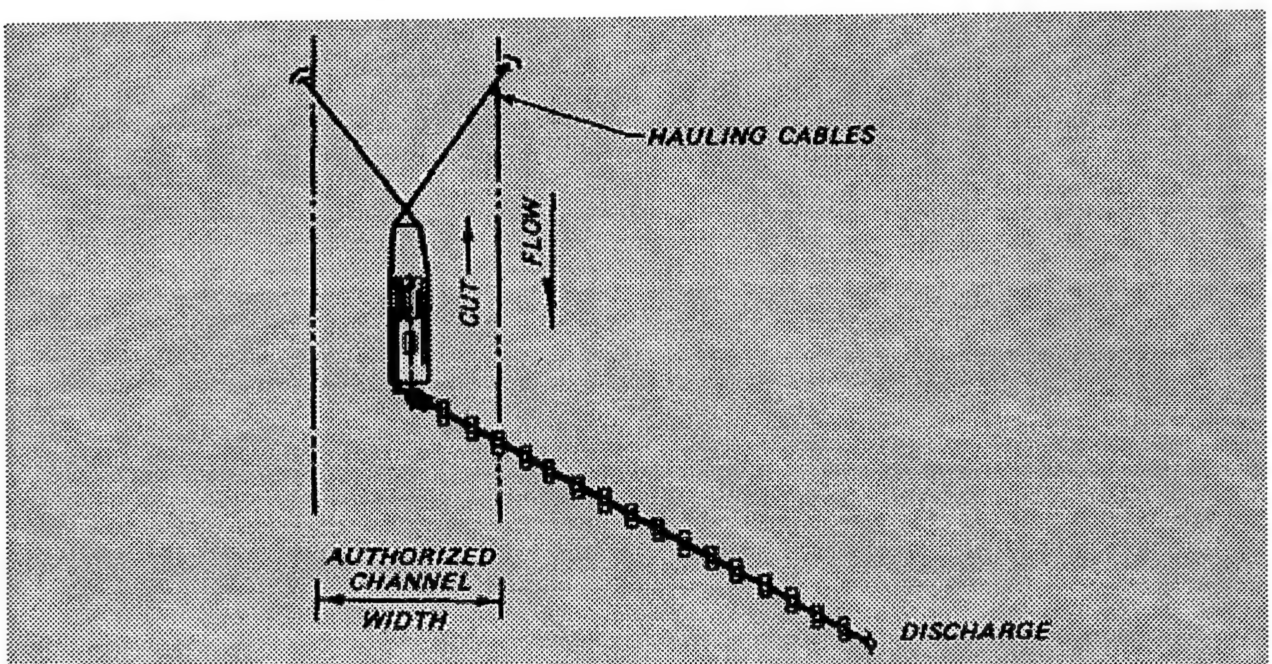


Figure 3-8. Operation of dustpan dredge (viewed from above).

Figure 7. Dustpan Operations Diagram

dredging. As the dredge begins to winch itself upstream, it turns on the water jets and lowers the dustpan. Winches and anchor cables control maneuvering. Because the connection between the dredge and the dustpan is rigid, this platform cannot be used in areas that have waves. It is primarily used on inland rivers. Depending on the makeup of the sediment to be removed, the dustpan can dredge up to 800 feet per hour.

The Dustpan dredge is a self-propelled dredge that is capable of moving from location to location rapidly. This dredge is also highly maneuverable, making minimum disruptions to the waterborne traffic. The Dustpan dredge is limited to the specific area of operations being rivers with soft sediments and no requirements to dispose of materials to upland sites.

**Sidecasting Dredge**

This is a shallow draft, seagoing vessel. It is a hydraulic type of dredge that was designed to remove material from the bar channels of small coastal inlets. The hull of this dredge is similar to that of the hopper dredge, but this type does not have the hoppers installed to collect the dredged materials. Instead, the materials are immediately pumped over the side of the vessel. This keeps the draft constant, which is ideal for unstablized, small inlets that prevent use of any other type of dredge in all but the most ideal conditions. The dredged materials, after being pumped over the side, are carried away by the littoral and tidal currents in the area.

Like the hopper dredges, the sidecasting dredge is self-propelled, making it easy to get from project to project. However, this dredge type does not have the ability to pump to upland disposal sites, so it cannot be used for dredging in areas where contaminated materials are present. Because this

dredge casts the dredged materials directly over the side, some of the materials can come back to the channel being cut due to the presence of currents.

**Dipper Dredge**

This dredge type is a barge-mounted shovel. The barge that the shovel is mounted on is held in place by spuds and the dredged material is placed in moored barges alongside of the dredger. Maneuvering is accomplished by lifting the forward spuds and then using the stern spuds and the bucket to move to the new location (see Figure 8). The barges, after being loaded, can go to open water disposal sites, or go to a site for upland disposal to be unloaded by mechanical or hydraulic equipment.

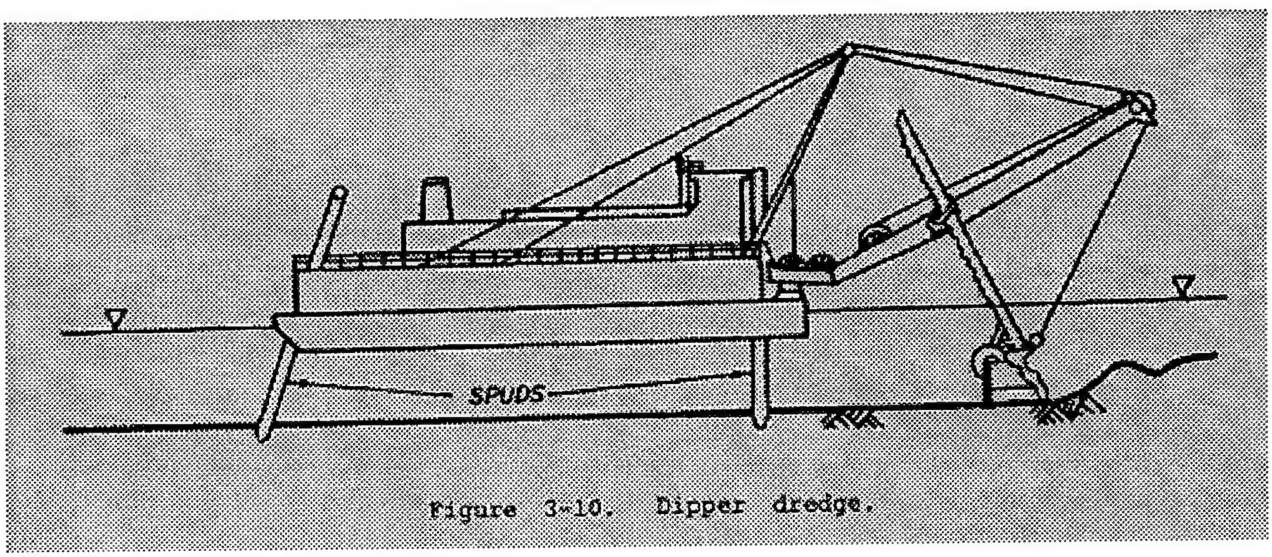


Figure 8. Dipper Dredge Diagram.

Because this is a mechanical dredge it is ideal for the removal of hard sediments and old foundations, pipes and other obstructions that the hydraulic dredges would not be able to get. This type of dredge needs less room to maneuver than most other types of dredges. It can be used to assist grounded vessels by digging out the shoals around the vessel. The dredged materials loaded on the barges will contain less excess water than the other types of dredges. Once loaded, the

barges can be taken great distances to be unloaded if there are not disposal sites nearby. This type of dredge does not have the efficiency of the hydraulic dredges and the level of efficiency is dependent on the number of barges available to service the dredge.

A similar type of mechanical dredge is the Bucket Dredge. It is identical to the Shovel Dredge except that is uses a bucket instead of a shovel for the digging of the sediment (see Figure 9). For that reason, it has a lesser effect on blasted rock materials.

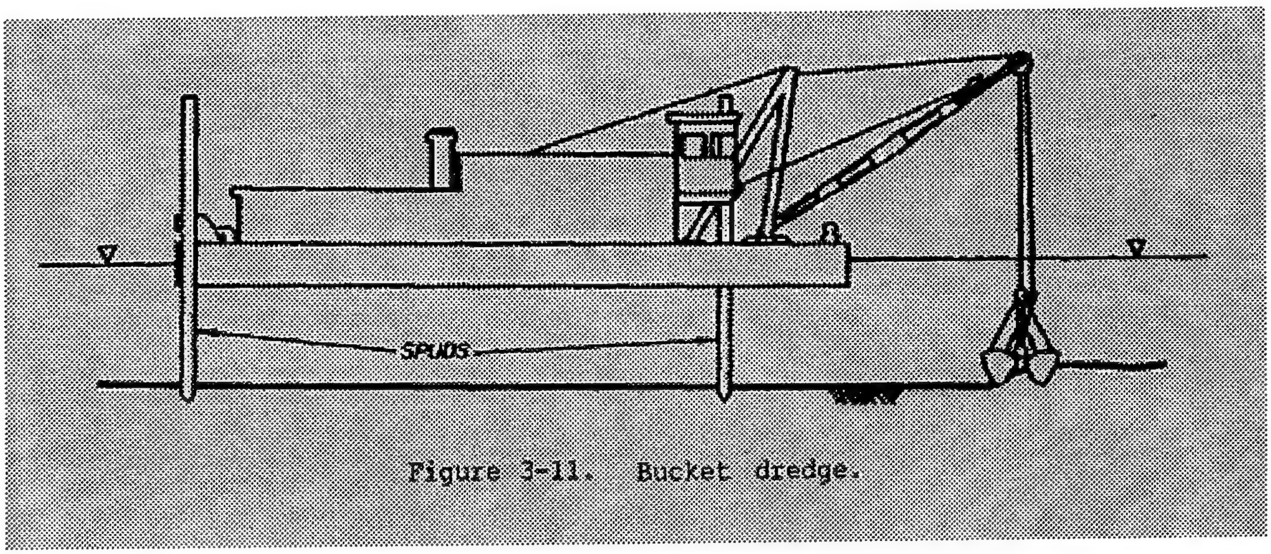


Figure 9. Bucket Dredge Diagram.

A list of the dredging contracts by fiscal year and dredge type is included in Appendix III.

A comparison of all dredge types is included in Appendix IV.

## NEW INOVATIONS

### UNDERWATER ARCHIMEDEAN SCREW VEHICLE (UASV)

Using the relatively new technology of global positioning and fiber optics, this new vehicle can surgically remove fine-grained sediments from thin layers at the bottom of harbors. This vehicle

gets pre-programmed before submerging. While underwater, it has fiber-optic cables that give operators on land the actual picture of what is happening below. With the global positioning and the viewer, this vehicle can be accurate up to 2 to 4 inches, allowing for tight operations around piers and other obstructions. The UASV uses a low-pressure supply pump to fluidize the bottom materials then the mixture is sucked through two dredge hoods to pipelines that carry the dredged materials back to shore. The UASV will be ideal for the removal of contaminated sediments where the contamination is contained in the top layers of the bottom material. The vehicle is specially suited to remove only the contaminated layers. The conventional dredges will be able to remove the remaining materials at a later time.

## HOPPER DREDGE RECIRCULATION SYSTEM

In normal Hopper Dredge operations, a certain amount of water and fine-grained materials are allowed to overflow from the hoppers. This causes a plume of fine-grained sediment to escape from the dredge. This can be environmentally harmful in areas where the water is pristine in quality or where the dredging of contaminated materials is occurring. The new system would incorporate the overflow into a closed loop system and reuse the water as pressure and transport water in the suction head. In addition to the environmental benefits, this system can decrease the pressure drop in the draghead, which can increase the suction power of the Hopper Dredge. This system is working successfully on Hopper Dredges in Europe.

## SUBMERSIBLE DREDGE PUMPS

This design improves existing pump technology by applying a mechanical seal as a shaft sealing instead of using a conventional gland. This makes the gland water and grease superfluous. The

maintenance becomes much easier, the deployability and the reliability become much greater due to the decrease in the piping required. The submersible pump can be outfitted with a wide range of suction devices including a cutter, dustpan, jet water ring or auger. This technology can be used dredge behind dams because of the almost limitless depth the pump can operate at. It can also be used to remove silt layers, sediments close to piers and other obstacles and to unload barges.

**PIVOTING GEARBOX**

This improvement to the Dustpan and Cutterhead Dredges makes it possible to adjust the angle of the ladder more than 45 degrees. This was possible previously only by the use of a hydraulic or electric submerged pump drive. This new device allows more efficient operations because it allows the operation of the dredge to continue without having down time to start a second inclined engine when operations require the ladder to be inclined greater than 45 degrees. Safety of the operators is also increased since the controls of the dredge are always at the onboard diesel engines.

**ELECTRONICS**

The greatest changes in dredging operations today come from the electronic equipment that is used to position the vessels. In the 1970's, the dredge operators had to be well versed in the use of navigation equipment as he was with the operations of his pumps. The vessel had to set in an area to be dredged and then fix its position using markers that were set out by the Corps of Engineers. This was a lengthy process and would have to be repeated if the vessel was to maneuver to a different location. Although the process was lengthy without the aid of computers, it was necessary since the contracts were written for the depth in a particular channel to be dredged (see Appendix V for Savannah Harbor Project Requirements). Any excess dredge materials that came

from areas outside of the contract area were the responsibility of the contractor. Dredge masters had to be sure their dredge was in the right position, and he had to check the tidal tables to ensure that he was dredging to the correct depth. Modern electronic equipment in the bridge of the vessel is making this process more streamlined. Using a combination of Global Positioning Systems and new multibeam echosounding systems, along with other GIS technologies for reporting, the dredge master no longer has to rely on the old navigation markers to determine his ship's position and can control navigation and positioning operations accurately from the chair on the bridge. From this position, the dredge master can download real time information to any computer on the internet. This is an advantage to the Army Corps because inspectors now can view the information that they previously had to be on site to see. Although the capabilities of the pumps and other equipment remain the same, streamlining the other processes required in dredging operations increases the overall efficiency.

## METHODS OF DISPOSAL

The Army Corps of Engineers Research Lab is continuously doing work to determine the best disposition of the dredged materials. In the United States, beaches are being restored and wetland created with the dredged materials. In Europe, Holland and the Netherlands are using the materials in their continuing war against the sea. The environmental impacts of such activities are continuously being reviewed. There are three main methods of dredged material disposal:

1. Open-water disposal
2. Confined disposal
3. Habitat development

These disposal methods are continuously reviewed to determine the most economical and environmentally friendly method.

## OPEN-WATER DISPOSAL

This method is simply disposing of the dredged materials at sea. The physical effects of this method include the removal of species from the dredge site and the burial of species at the disposal site. Studies have shown that the sites are recolonized from a period of a few months up to two years. Sometimes the recolonization occurs from opportunistic organisms, which are not normally the dominant species in the area.

## CONFINED DISPOSAL

This method uses diked areas to confine the area in which the dredged material is stored for disposal. The disposal area will allow inflow over a weir. The first materials to settle out are the gravel and other large materials. The smaller grained materials stay suspended in the water. At the opposite end of the disposal area, there will be a weir to allow effluent to be removed after the sediments have had time to settle out. The turbidity in the effluent is checked before the water is allowed to return the river/harbor. The dredged materials that have settled and dried can be put to productive applications. Potential productive uses include:

1. Landfill and construction material
2. Surface mine reclamation
3. Sanitary landfill cover material
4. Agricultural land enhancement

The containment areas themselves can be used for recreational or industrial sites when it is filled.

## HABITAT DEVELOPMENT

Dredged material has been extensively used to restore and establish wetlands. Where proper sites can be located and government and private agency cooperation can be coordinated, wetland restoration is a relatively common and technically feasible use of dredged material. Wetland restoration or rehabilitation using dredged material is usually a more acceptable alternative to creation of a new wetland. Many of the world's natural wetlands are degraded or impacted, or have been destroyed, and the recovery of these wetlands is more important than creation of new ones. Creation of a new wetland would also mean replacing one habitat type with another, which is not always desirable. Long-term planning, design, maintenance, and management are necessary to maintain a created wetland. Wetland restoration using dredged material can be accomplished in several ways. For example, dredged material can be applied in thin layers to bring degraded wetlands up to an intertidal elevation, as has been done extensively in south Louisiana. Dewatered dredged material can be used in wind and wave barriers to allow native vegetation to regrow and restore the viability of a wetland. Dredged material sediment can be used to stabilize eroding natural wetland shorelines or nourish subsiding wetlands. Dewatered dredged material can also be used to construct erosion barriers and other structures that aid in restoring a degraded or impacted wetland (see Appendix VI for examples of recent Army Corps of Engineers wetlands creation or wildlife habitat projects).

# MODERN DREDGING PROJECTS AROUND THE WORLD

## HONG KONG AIRPORT

In Hong Kong there is a great need for land. Due to the rough geology of the area, flat land is especially necessary. The old airport was overcrowded and could not keep up with the daily needs

of a modern international airport. The Airport Core Program was formed in 1989 to start explorations into the possibility of using dredging to reclaim land to make a site for the required new airport. This project required a formidable amount of foundations planning and study to determine the stratigraphy of the area and what were contained in the formations below the surface. This had to be done just to find a suitable location for the new airport. The location to be used sits on the Chek Lap Kok formation and the project joined two islets. All together, almost 6 billion cubic feet of fill were used to create the airport site, which sits on 3084 acres of reclaimed land.

During the construction of this project, 16 of the worlds 18 largest hopper dredges were being used. However, more impressive was the creativeness used in the mapping of the seafloor and the charting of the formations below. Concern for the environmental impacts of the project were, and still continue to be of great concern. Remote sensing for turbidity by SPOT satellites, Acoustic Doppler Current Profiler, Sidescan Sonar, Chirp Profiling and Profiling Siltmeter were all used to identify and control the amount of turbidity that was created by the dredging operations.
Hong Kong continues to do land reclamation operations as the need for space continues to grow. The existing program will continue to 2015 and will require an additional 10.6 billion cubic feet of fill. It is projected that 5% of the land area of Hong Kong will be reclaimed land at the completion of this program. The airports at Sydney, Australia and Kansai, Japan have also been built or expanded on reclaimed land in the 1990's.

## SCANDINAVIAN CONNECTION

The creation of a Trans-European rail and road network is one of the goals of the European Union. In the 1990s two significant infrastructure projects to achieve this goal have been the construction

of the Storebaelt East Bridge in Denmark and the Øresund Fixed Link connecting Denmark with Sweden.

Both projects are monumental. The Storebaelt consists of a combined traffic and railway bridge extending on the western side from Funen to the island Sprogø and a railway tunnel and a traffic bridge on the eastern side from Sprogø to the mainland (Zealand). The East Bridge is 4.2 miles long, the longest suspension bridge ever built. Dredging, cleaning and the stones placement for the substructure of the bridge pylons was excruciatingly precise work. The Øresund Fixed Link, totaling 9.9 miles, consists of a dual track railway and a four-lane motorway connecting Copenhagen, Denmark with Malmö, Sweden.

Millions of cubic feet of materials were dredged and millions of tons of stones were handled while digging the tunnel trench and building the artificial islands and peninsula for the highway to tunnel to bridge to highway connections. Finally hydraulic compensation areas were deepened to ensure the stability of the marine environment. Totaling all aspects of the works, some 247 million cubic feet of material has been dredged. The bridge was opened in the summer of 1999.

Both projects have adhered to the strictest environmental restrictions, design tolerances and have withstood many risks including difficult weather conditions. Reclamation works at Sprogø, Denmark, an island in the Storebaelt.

## NORFRA PIPELINE

Dredging works related to laying pipeline for offshore projects is an increasingly significant activity for the dredging industry. Take the NORFRA gas pipeline stretching through the North Sea from Norway to Denmark, Germany, the Netherlands, Belgium and arriving in France. Of 520 miles of pipeline, 357 miles had to be buried in the seabed in order to prevent damage from shipping traffic, anchors and fishing nets. Fighting against time, since bad weather in the North Sea is a given, the work encompassed presweeping of sand dunes on the sea bed, pretrenching, dredging, backfilling and civil works on shore.

Presweeping involved the dredging of 42 million cubic feet to provide a minimum 33-foot wide pipelay corridor. After the pipeline was installed, post-trenching lowered the pipeline from its laid level of 2 feet to 6 feet below the seabed. Some 706,000 cubic feet of water per hour were injected into the sea bottom under the pipeline, and by its own weight the gas pipeline settled into the resulting deeper trench. Sea-dredged gravel was then placed with a minimum of 3 feet above the pipeline. On land at Dunkirk, the pipeline crosses the Canal des Dunes through a tunnel and has been further installed up to the terminal building.

Owing to new technologies, extensive safety measures and keeping to a tight time schedule, the project was completed with a considerable underrun, 20 percent below the targeted budget. For the NORFRA pipeline installation on land, a sea-going cutter is dredging at the shore approach in front of the cofferdam at Dunkirk, France.

# CONCLUSION

From humble beginnings, the dredging industry has grown exponentially in the past century. Before the 1900's, each port maintained its own dredging needs. Today, there are multinational conglomerates that are required to meet the increasing needs of today's deeper draft vessels. The projects being undertaken have grown in size and complexity as well. The machinery used today has not had major changes in design for the last 50 years. The most innovative changes have occurred in the bridge of the ship for command and control. The modern electronic devices mean that fewer personnel are required to do the job, and the job is getting done with greater accuracy. Other problems continue to persist, though. The largest problem for the engineers to tackle, however, remains the need to be environmentally friendly in all operations, most notably disposal of material.

# APPENDIX I

# CORPS OF ENGINEERS AND INDUSTRY TOTALS

# BY YEAR

U.S. Army Corps of Engineers Dredging Program
Summary of Corps and Industry Activities
Dollars and Yards (in millions)
Date: 28-Feb-1999 Final Revised

**CORPS AND INDUSTRY**

| FISCAL | DOLLARS | | | CUBIC YARDS | | |
|---|---|---|---|---|---|---|
| YEAR | MAINT | NEW WK | TOTAL | MAINT | NEW WK | TOTAL |
| 1963 | $59.00 | $107.00 | $166.00 | 217.00 | 263.00 | 480.00 |
| 1964 | $59.00 | $83.00 | $142.00 | 217.00 | 192.00 | 409.00 |
| 1965 | $68.00 | $80.00 | $148.00 | 250.00 | 166.00 | 416.00 |
| 1966 | $69.00 | $68.00 | $137.00 | 254.00 | 136.00 | 390.00 |
| 1967 | $64.00 | $46.00 | $110.00 | 235.00 | 92.00 | 327.00 |
| 1968 | $70.00 | $42.00 | $112.00 | 249.00 | 89.00 | 338.00 |
| 1969 | $70.00 | $45.00 | $115.00 | 233.00 | 109.00 | 342.00 |
| 1970 | $92.00 | $36.00 | $128.00 | 303.00 | 89.00 | 392.00 |
| 1971 | $93.00 | $48.00 | $141.00 | 278.00 | 79.00 | 357.00 |
| 1972 | $98.00 | $43.00 | $141.00 | 256.00 | 59.00 | 315.00 |
| 1973 | $112.00 | $45.00 | $157.00 | 276.00 | 36.00 | 312.00 |
| 1974 | $140.00 | $36.00 | $176.00 | 338.00 | 48.00 | 386.00 |
| 1975 | $146.00 | $61.00 | $207.00 | 267.00 | 65.00 | 332.00 |
| 1976 | $173.00 | $72.00 | $245.00 | 255.00 | 46.00 | 301.00 |
| 1977 | $175.00 | $57.00 | $232.00 | 253.00 | 44.00 | 297.00 |
| 1978 | $214.00 | $93.00 | $307.00 | 210.00 | 71.00 | 281.00 |
| 1979 | $241.00 | $83.00 | $324.00 | 234.00 | 48.00 | 282.00 |
| 1980 | $305.00 | $98.00 | $403.00 | 243.00 | 54.00 | 297.00 |
| 1981 | $344.00 | $115.00 | $459.00 | 262.00 | 97.00 | 359.00 |
| 1982 | $310.00 | $135.00 | $445.00 | 217.00 | 55.00 | 272.00 |
| 1983 | $355.00 | $89.00 | $444.00 | 254.00 | 33.00 | 287.00 |
| 1984 | $456.00 | $94.10 | $550.10 | 294.00 | 52.47 | 346.47 |
| 1985 | $385.74 | $63.40 | $449.14 | 273.24 | 30.00 | 303.24 |
| 1986 | $322.00 | $64.00 | $386.00 | 282.00 | 33.00 | 315.00 |
| 1987 | $288.30 | $99.19 | $387.49 | 215.13 | 43.12 | 258.25 |
| 1988 | $295.42 | $178.03 | $473.44 | 212.80 | 72.64 | 285.44 |
| 1989 | $318.12 | $164.00 | $482.11 | 281.13 | 52.73 | 333.86 |
| 1990 | $305.99 | $187.49 | $493.48 | 209.67 | 63.34 | 273.01 |
| 1991 | $423.07 | $89.43 | $512.50 | 271.60 | 28.40 | 300.00 |
| 1992 | $369.49 | $116.24 | $485.73 | 216.34 | 27.80 | 244.14 |
| 1993 | $410.23 | $104.66 | $514.88 | 235.51 | 33.50 | 269.00 |
| 1994 | $426.71 | $100.82 | $527.53 | 264.71 | 36.96 | 301.67 |
| 1995 | $408.19 | $122.84 | $531.03 | 217.13 | 33.99 | 251.12 |
| 1996 | $425.02 | $89.74 | $514.77 | 234.28 | 24.37 | 258.64 |
| 1997 | $494.45 | $127.48 | $621.93 | 252.74 | 32.18 | 284.93 |
| 1998 | $532.50 | $178.00 | $710.50 | 211.30 | 27.30 | 238.60 |

U.S. Army Corps of Engineers Dredging Program
Summary of Corps of Engineers Activities
Dollars and Yards (in millions)
Date: 28-Feb-1999 Final Revised
**CORPS OF ENGINEERS**

| FISCAL DOLLARS | | | | CUBIC YARDS | | |
|---|---|---|---|---|---|---|
| YEAR | MAINT | NEW WK | TOTAL | MAINT | NEW WK | TOTAL |
| 1963 | $27 | $8 | $35 | 137 | 25 | 162 |
| 1964 | $30 | $6 | $36 | 108 | 18 | 126 |
| 1965 | $34 | $7 | $41 | 123 | 20 | 143 |
| 1966 | $34 | $8 | $42 | 123 | 22 | 145 |
| 1967 | $36 | $5 | $41 | 130 | 14 | 144 |
| 1968 | $36 | $7 | $43 | 116 | 22 | 138 |
| 1969 | $39 | $5 | $44 | 141 | 14 | 155 |
| 1970 | $43 | $6 | $49 | 143 | 13 | 156 |
| 1971 | $46 | $6 | $52 | 145 | 13 | 158 |
| 1972 | $49 | $6 | $55 | 145 | 13 | 158 |
| 1973 | $50 | $6 | $56 | 145 | 8 | 153 |
| 1974 | $63 | $7 | $70 | 183 | 7 | 190 |
| 1975 | $75 | $7 | $82 | 157 | 7 | 164 |
| 1976 | $86 | $4 | $90 | 132 | 3 | 135 |
| 1977 | $85 | $1 | $86 | 127 | 1 | 128 |
| 1978 | $90 | $2 | $92 | 92 | 3 | 95 |
| 1979 | $87 | $8 | $95 | 87 | 3 | 90 |
| 1980 | $92 | $3 | $95 | 81 | 1 | 82 |
| 1981 | $104 | $0 | $104 | 88 | 0 | 88 |
| 1982 | $76 | $0 | $76 | 60 | 0 | 60 |
| 1983 | $64 | $1 | $65 | 48 | 1 | 49 |
| 1984 | $80 | $1 | $81 | 49 | 0 | 49 |
| 1985 | $73 | $0 | $73 | 65 | 0 | 65 |
| 1986 | $80 | $0 | $80 | 64 | 0 | 64 |
| 1987 | $66.0 | $0.3 | $66.3 | 47.7 | 0.3 | 48.0 |
| 1988 | $73.4 | $0.1 | $73.5 | 58.2 | 0.1 | 58.3 |
| 1989 | $68.5 | $0.0 | $68.5 | 58.7 | 0.0 | 58.7 |
| 1990 | $61.8 | $0.0 | $61.8 | 35.0 | 0.0 | 35.0 |
| 1991 | $99.6 | $0.0 | $99.6 | 62.4 | 0.0 | 62.4 |
| 1992 | $89.2 | $0.0 | $89.2 | 52.4 | 0.0 | 52.4 |
| 1993 | $75.0 | $0.7 | $75.8 | 38.3 | 0.1 | 38.4 |
| 1994 | $84.3 | $0.0 | $84.3 | 52.5 | 0.0 | 52.5 |
| 1995 | $88.8 | $6.5 | $95.3 | 53.8 | 7.9 | 61.7 |
| 1996 | $85.4 | $0.0 | $85.4 | 52.5 | 0.0 | 52.5 |
| 1997 | $95.9 | $0.2 | $96.1 | 67.8 | 0.0 | 67.8 |
| 1998 | $76.6 | $0.0 | $76.6 | 42.4 | 0.0 | 42.4 |

# APPENDIX II

# OPERATIONAL CHARACTERISTICS OF CUTTERHEAD AND HOPPER DREDGES

## OPERATIONAL CHARACTERISTICS

The following table shows the specifications of some cutterhead and wheel dredges produced by Ellicott International:

| Series | Discharge Diameter | Nominal Digging Depth | Pump Horse Power | Auxiliary Horse Power | Nominal Pump Capacity |
|---|---|---|---|---|---|
| **Dragon Cutterhead Dredges** | | | | | |
| 370HP | 10 inches | 20 feet | 410 | N/A | up to 320 cy/hr |
| 670 | 12 - 14 inches | 26 feet | 715 | N/A | 100 - 600 cy/hr |
| 1170 | 14 - 16 inches | 33 feet | 855 | 290 | 150 – 700 cy/hr |
| 1870 | 18 - 20 inches | 50 feet | 1280 | 475 | 200 – 1200 cy/hr |
| **Super-Dragon Cutterhead Dredges** | | | | | |
| 4170 | 20 - 27 inches | 58 feet | 2560 | 1510 | 400 – 2400 cy/hr |
| 4500 | 24 - 27 inches | 58 feet | 3400 | 1900 | 400 – 2400 cy/hr |
| 4900 | 24 - 27 inches | 58 feet | 3400 | 1610 | 400 – 2400 cy/hr |
| 5770 | 27 - 33 inches | 58 feet | 4000 | 900 | 700 - 3300 cy/hr |
| 6000 | 27 - 33 inches | 58 feet | 4000 | 1900 | 700 - 3300 cy/hr |
| 7000 | 27 - 33 inches | 70 feet | 5000 | 3310 | 700 - 3500 cy/hr |
| 10000 | 27 - 33 inches | 100 feet | 9000 | 3310 | 700 - 3500 cy/hr |
| **Wheel Dragon Bucketwheels** | | | | | |
| B-890 | 14 inches | 26 feet | 624 | 210 | 100 - 600 cy/hr |
| B-1990 | 16 - 18 inches | 36.5 feet | 1280 | 475 | 200 – 1000 cy/hr |
| B-4000 | 24 inches | 50 feet | 3400 | 955 | 20 – 2300 cy/hr |

Table 3-1. Pertinent Characteristics of Corps of Engineers Hopper Dredges.

| Name | Hopper Capacity cu yd | Dredged Pumps Number hp | Dredged Pumps Size Drive | Light Loaded Speed mph | Hull Material Length | Hull Beam Depth | Draft Loaded | Dredging Depth Max | Vertical Clearance Required | Regional Location | Special Capability |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BIDDLE | 3060 | 2<br>1150 | 28"<br>Electric | 17.3<br>14.4 | Steel<br>351'9" | 60'0"<br>30'0" | 24'9" | 62' | 83' | West Coast | None |
| ESSAYONS | 6000 | --[a] | -- | 15.4 | Steel<br>350' | 68'<br>35' | 27' | 80' | — | Gulf Coast | Direct pumpout |
| HAINS | 855 | 1<br>410 | 20"<br>Electric | 14.1<br>13.1 | Steel<br>215'10" | 40'4"<br>13'6" | 13'0" | 36' | 69' | Great Lakes | Direct pumpout<br>Sidecasting |
| WHEELER | 8400 | — | — | 16.1 | Steel<br>409' | 78'<br>39' | 29'5" | 30' | — | Gulf Coast | Direct pumpout |
| YAQUINA | 825 | — | — | 11.5 | Steel<br>200' | 58'<br>17' | 12' | 45' | — | West Coast | Direct pumpout |
| MACFARLAND | 3140 | 2<br>1867 | 34"<br>Electric | 15.4<br>14.0 | Steel<br>319'8" | 72'0"<br>33' | 22'0" | 55' | 90' | East Coast | Direct pumpout<br>Sidecasting |
| MARKHAM | 2780 | 2<br>650 | 23"<br>Electric | 16.7<br>14.4 | Steel<br>339'6" | 62'0"<br>28'0" | 19'4" | 45' | 90' | Great Lakes | Direct pumpout |
| PACIFIC | 500 | 1<br>340 | 18"<br>Electric | 11.5<br>9.8 | Steel<br>180'3" | 38'0"<br>14'0" | 12'0" | 45' | 70' | West Coast | None |

[a] Data unavailable.

# APPENDIX III

# NUMBER OF CONTACTS AWARDED BY FISCAL YEAR AND DREDGE TYPE

Number of dredging contracts awarded by Fiscal Year and type of dredge

| | Fiscal Year | | | |
|---|---|---|---|---|
| **Dredge Type** | **95** | **96** | **97** | **98** |
| Bucket | 41 | 26 | 43 | 36 |
| Dustpan | 2 | 0 | 1 | 1 |
| Hopper | 34 | 31 | 38 | 37 |
| Non-conventional | 0 | 1 | 1 | 2 |
| Pipeline | 128 | 117 | 107 | 96 |
| Combo all types | 3 | 3 | 4 | 4 |
| Pipeline+Bucket | 1 | 3 | 5 | 4 |
| Pipeline+Hopper | 0 | 3 | 2 | 6 |
| Hopper+Bucket | 3 | 3 | 0 | 1 |
| **TOTAL** | **212** | **187** | **201** | **187** |

Quantity in cubic yards for awarded dredging contracts for Fiscal Year by type of dredge

| | Fiscal Year | | | |
|---|---|---|---|---|
| **Dredge Type** | **95** | **96** | **97** | **98** |
| Bucket | 18,493,700.00 | 9,441,978.00 | 14,586,243.00 | 18,663,002.00 |
| Dustpan | 11,367,157.00 | 0.00 | 5,000,000.00 | 5,000,000.00 |
| Hopper | 42,058,000.00 | 41,831,800.00 | 62,962,556.00 | 62,845,341.00 |
| Non-conventional | 0.00 | 20,000.00 | 10,000.00 | 7,013,500.00 |
| Pipeline | 120,183,154.00 | 121,830,153.00 | 107,291,452.00 | 130,138,379.00 |
| Combo all types | 4,502,604.00 | 3,761,000.00 | 33,300,635.00 | 15,230,000.00 |
| Pipeline+Bucket | 85,000.00 | 330,000.00 | 1,249,500.00 | 285,000.00 |
| Pipeline+Hopper | 0.00 | 4,450,110.00 | 5,584,800.00 | 4,980,172.00 |
| Hopper+Bucket | 1,748,800.00 | 5,208,000.00 | 0.00 | 900,000.00 |
| **TOTAL** | **198,569,415.00** | **186,873,041.00** | **229,985,186.00** | **245,055,394.00** |

Contract bid dollars for awarded dredging contracts for Fiscal Year by type of dredge

| | Fiscal Year | | | |
|---|---|---|---|---|
| **Dredge Type** | **95** | **96** | **97** | **98** |
| Bucket | $ 98,839,025.00 | $ 38,554,117.00 | $157,146,431.00 | $ 97,505,293.00 |
| Dustpan | $ 12,781,761.00 | $ 0.00 | $ 9,972,147.00 | $ 9,509,851.00 |
| Hopper | $ 91,619,432.00 | $ 85,407,719.00 | $106,487,801.00 | $109,938,332.00 |
| Non-conventional | $ 0.00 | $ 53,025.00 | $ 344,500.00 | $ 1,626,175.00 |
| Pipeline | $206,761,024.00 | $222,752,050.00 | $224,397,336.00 | $270,619,950.00 |
| Combo all types | $ 15,985,680.00 | $ 8,910,990.00 | $183,191,705.00 | $ 19,453,964.00 |
| Pipeline+Bucket | $ 1,865,700.00 | $ 1,839,650.00 | $ 4,407,365.00 | $ 1,872,400.00 |
| Pipeline+Hopper | $ 0.00 | $ 32,754,102.00 | $ 32,190,800.00 | $ 25,895,407.00 |
| Hopper+Bucket | $ 7,267,400.00 | $ 15,363,635.00 | $ 0.00 | $ 3,188,200.00 |
| | **$435,118,023.00** | **$405,635,288.00** | **$718,138,085.00** | **$539,609,572.00** |

Fiscal Year = 1 October to 30 September

Dredge - powerful machines used to remove earth and other sediments from the bed of a body of water. The various types of dredges include:

Bucket - the term used in this report to represent all types of mechanical dredges, which are used to excavate and lift the material mechanically by means of buckets or scoops.

Dustpan - hydraulic, self-propelled dredge that uses a suction mouth, shaped like a large dustpan or vacuum cleaner, fitted with water jets for dislodging material from the bottom of the channel.

Hopper - self propelled floating plant which is capable of dredging material, storing it onboard, transporting it to a disposal area, and dumping it.

Nonconventional type - type of specialized dredge which combines the features of hydraulic and mechanical dredges.

Pipeline - a hydraulic dredge whose prime function is to excavate and move material hydraulically to another location without rehandling. Hydraulic dredging requires dilution with water for material pickup and transport through a pipeline to a disposal location.

Sidecaster - self propelled trailing suction dredge that discharges material to one side of the excavation through a suspended discharge pipe.

All Types - combination of three or more types of dredges.

Pipeline & Bucket - dredging project which uses a pipeline and a bucket dredge.

Pipeline & Hopper - dredging project which uses a pipeline and a hopper dredge.

Hopper & Bucket - dredging project which uses a hopper and a bucket dredge

# APPENDIX IV

# COMPARISON OF ALL DREDGE TYPES

Table 3-5. Summary of Dredge Operating Characteristics[a]

| Dredge Type | Percent Solids in Slurry by Weight[b] | Turbidity Caused | Open-Water Operation | Vessel Draft ft | Approx. Range of Production Rates cu yd/hr | Dredging Depths ft Minimum | Dredging Depths ft Maximum | Limiting Wave Height ft | Limiting Current | Lateral Dredging Accuracy[c] ft |
|---|---|---|---|---|---|---|---|---|---|---|
| Dipper | in situ | high | yes[d] | e | 30-500 | 0[f] | 50 | $<3$[g] | h | 1/2 |
| Bucket | in situ | high[i] | yes[d] | e | 30-500 | 0[f] | 100[j] | $<3$[g,k] | h | 1 |
| Dustpan | 10-20% | avg. | no | 5-14 | 1200-5,700 | 5-14 | 50-60[l] | $<3$ | h | 2-3 |
| Cutterhead | 10-20% | avg. | yes[d] | 3-14 | 25-10,000 | 3-14 | 12-65[l] | $<3$ | h | 2-3 |
| Hopper | 10-20% | avg. | yes | 12-31 | 500-2,000 | 10-28 | 80 | $<7$ | h | 10 |
| Sidecasting | 10-20% | high | yes | 5-9 | 325-650 | 6 | 25 | $<7$ | h | 10 |
| Special-Purpose | 10-20% | avg. | yes | 5-8 | 250 avg. | 8 | 20 | $<7$ | h | 10 |

[a] Prepared by WES.

[b] Percent solids could theoretically be 0, but these are normal working ranges. Percent solids = $\frac{\text{wt. of dry sediment}}{\text{wt. of wet slurry}}$.

[c] Vertical accuracies are generally within $\pm 1$ ft.

[d] Limited operation in open water possible, depending on hull size and type and wave height.

[e] Depends on floating structure; if barge-mounted, approximately 5- to 6-ft draft.

[f] Zero if used alongside of waterway; otherwise, draft of vessel will determine.

[g] Depends on supporting vessel--usually barge-mounted.

[h] Literature implies that water current hinders dredging operations, but references avoid establishing maximum current limitations. For most dredges, limiting current is probably in the 3- to 5-knot range, with hopper and dustpan dredges able to work at currents of perhaps 7 knots.

[i] Low, if watertight bucket is used.

[j] Demonstrated depth; theoretically could be used much deeper.

[k] Theoretically unaffected by wave height; digging equipment not rigid.

[l] With submerged dredge pumps, dredging depths have been increased to 100 ft or more.

# APPENDIX V

# SAVANNAH HARBOR PROJECT DIMINSIONS

Existing Savannah Harbor project dimensions

| Station | Project Depth (-FT, MLW) | Bottom Width (FT) | Advance Maintenance (FT) | Maintenance Dredging Depth (-FT, MLW) |
|---|---|---|---|---|
| 112+500 | | | | |
| | 30 | 200 | 2 | 32 |
| 105+500 | | | | |
| | 36 | 400 | 2 | 38 |
| 103+000 | | | | |
| | 42 | 400 | 0 | 42 |
| 102+000 | | | | |
| | 42 | 400 | 2 | 44 |
| 100+000 | | | | |
| | 42 | 500 | 2 | 44 |
| 79+000 | | | | |
| | 42 | 500 | 2 | 44 |
| 70+000 | | | | |
| | 42 | 500 | 4 | 46 |
| 50+000 | | | | |
| | 42 | 500 | 4 | 46 |
| 41+000 | | | | |
| | 42 | 500 | 4 | 46 |
| 24+000 | | | | |
| | 42 | 500 | 2 | 44 |
| 0+000 | | | | |
| | 42 | 500 | 2 | 44 |
| -14+000B | | | | |
| | 44 | 600 | 0 | 44 |
| -60+000B | | | | |

All dredging projects include payment for 2 feet of allowable overdepth below these depths if it is dredged by the contractor.

# APPENDIX VI

# EXAMPLES OF THE USES FOR DREDGED MATERIALS

Beneficial Use(s):Land Creation

Wildlife Habitats
Lead Agency: USAE South Atlantic Division and North Atlantic Division
Placement Date(s): Most constructed when the Atlantic Intracoastal Waterway was built in 1930's through 1940's.
Location: Most islands are located in the Atlantic Intracoastal Waterway adjacent to the channel from Florida to Long Island, in Chesapeake Bay, or in major harbor areas (Savannah, Charleston, Norfolk, Philadelphia, New York)
Placement Method: Information not available
Substrate Type: Most are sand or silty sand, although those in harbors contain more silt.
Energy Source Wind fetches and wave energies vary; all are affected to some extent by barge and boat wakes.
Project Size: Varies from 0.5 acres to over 100 acres
Project Costs: Less than $1.00 per CY.

Comments:
Wildlife islands were built using dredged material. Most older islands did not have physical protection but the newer islands and CDF's have riprap or some other protective structure. All the Atlantic Intercoastal Water Way islands were colonized naturally with the exceptions of Core Sound and Barren Island, which had shorelines planted with cordgrass. Few records are available due to the age of most projects.

Monitoring:
Islands in New Jersey, North Carolina, and Florida were intensively monitored for vegetation and wildlife during the Dredged Material Research Program. Other islands periodically surveyed for waterbird colonies by state agencies, local birding groups, and in a FWS nationwide survey in the early 1980's. National Park Service and Rutgers University has monitored islands in Long Island Sound and vicinities.

Gulf Coast Intracoastal Waterway

Beneficial Use(s):Land Creation
Wildlife Habitats
Lead Agency:USAE South Atlantic Division, Southwestern Division, and Mississippi Valley Division
Placement Date(s):Most islands built in the 1930-1950's
Location:Islands located throughout the Gulf Coast Intracoastal Waterway system and in major harbors such as Mobile, Tampa, and Galveston.
Placement Method:Information not available
Substrate Type:Primarily sand with some silty sand or silt bases.
Energy SourceDepends upon location within the waterway; most have some wave and wind actions; all are affected by barge and boat wakes.
Project Size:Sizes of islands range from 0.5 acres to over 100 acres.
Project Costs:Less than $1.00 per CY.

Comments:
Wildlife islands were created using dredged material.
Riprap or well-engineered dikes were used to protect the CDF=s but not the older islands. All older islands were colonized naturally. Some additions or newer islands were partially planted. Most islands are so old that records have been lost.

Monitoring:
Most islands have not had any monitoring, although over 50 percent in any given year will have 1 or more waterbird colonies on them. In Texas, the Fish-eating Bird Survey collected annual data on all colonies, but does not distinguish dredged material or natural islands. Periodic data have been collected in Louisiana, Alabama, Mississippi, and Florida. Extensive Dredged Material Research Program data exists on these bird islands, including vegetation in and out of colonies, feeding information, and nesting populations and relationships.

Atchafalaya River Delta, LA

Beneficial Use(s):Wildlife Habitats
Wetland Restoration
Lead Agency:USACE New Orleans District, Mississippi Valley Division
Placement Date(s):At various times in the 1970's and 1980's
Location:Mouth of the Atchafalaya River, Louisiana
Placement Method:Information not available
Substrate Type:Silt
Energy SourceRiver currents, some barge wakes within the Gulf
Intracoastal Waterway, some wave energy from the Gulf
Project Size:Multiple sites of several acres each
Project Costs:Estimated $2.00 per cy

Comments:
Maintenance dredged material used for marsh and bird island nourishment. Vegetation was allowed to colonize naturally (in case of bird islands, vegetation is not encouraged).

Monitoring:
Very limited. General Observations were done by New Orleans District and Louisiana DNR personnel

Buttermilk Sound, GA

Beneficial Use(s):Wetland Restoration
Lead Agency:USACE Savannah District, South Atlantic Division
Placement Date(s):Island mound formed in 1960's; marsh creation project begun in 1974
Location:Atlantic Intracoastal Waterway, Buttermilk Sound, mouth of Altamaha River, Georgia, north of Brunswick
Placement Method:Information not available
Substrate Type:Sand
Energy SourceMinimal
Project Size:Entire island positively influenced by project was over 20 acres; initial project was seven acres.
Project Costs:$0.98 per cy; with approximately $2,500 per acre for planting experimental area; site preparation costs were $2,000

Comments:
Previously deposited maintenance dredged material sand smothered the existing salt marsh. This project shaved down the mound to intertidal elevation and planted vegetation to restore the salt marsh. Eight high and low marsh species were planted, including smooth cordgrass, saltmeadow cordgrass, big cordgrass, marsh elder, sea oxeye, saltgrass, other minor species in the test plots. Over time, site was dominated by smooth, big, and saltmeadow cordgrasses typical of surrounding marshes.

Monitoring:
Long-term data were collected by University of Georgia and Waterways Experiment Station (pre-, during, and post-construction intensive monitoring).

Columbia River Islands, OR

Beneficial Use(s):Land Creation
Wildlife Habitats
Lead Agency:USAE Portland District, Northwestern Division
Placement Date(s):In the 1950's with some additions of maintenance dredged material on a regular basis.
Location:Several Islands located in and around Lewis and Clark and Columbia White-tailed Deer National Wildlife Refuges in the lower Columbia River, Oregon.
Placement Method:Information not available
Substrate Type:Sand
Energy SourceStrong wind and wave energies, 8-ft tides
Project Size:Several islands of varying sizes
Project Costs:Information no longer available due to age of projects.

Comments:
Land was created and wildlife habitat was developed using dredged material. Vegetation was via natural colonization. No protection was provided from the energy sources. Limited records due to project age.

Monitoring:
Primarily limited to the 1970's. Extensive studies done on Mott, Sand, and Rice Islands during the Dredged Material Research Program to document vegetation and soil successional changes on manmade islands and their use as habitats. Regular observations of eagle and other wildlife are made on the islands.

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